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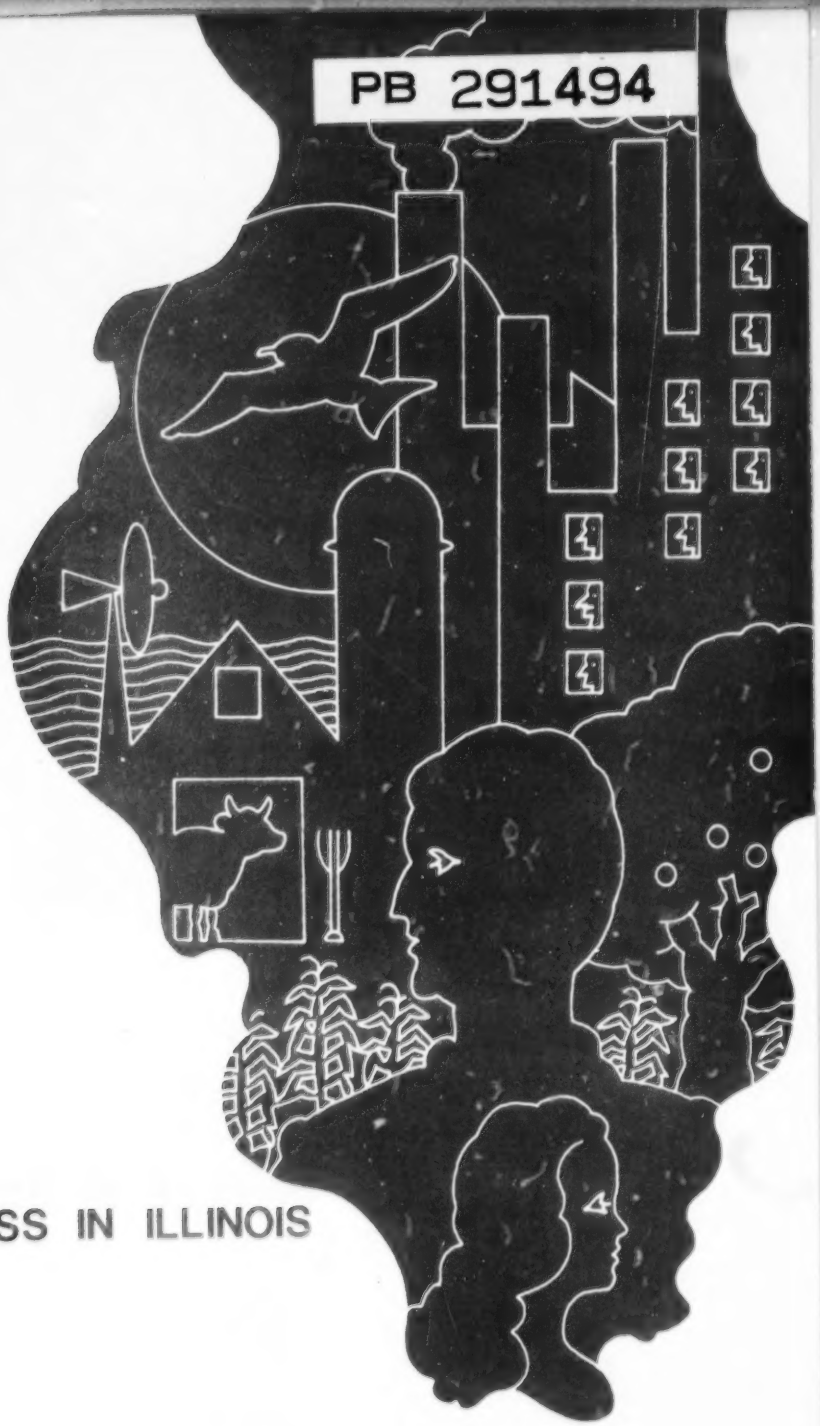

SEDIMENT AND SOIL LOSS IN ILLINOIS
SUMMARY

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SEDIMENT AND SOIL LOSS IN ILLINOIS

SUMMARY

by

Illinois Environmental Protection Agency

Based Upon a Report by the

Illinois State Water Survey

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Project No. 20.085

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INTRODUCTION

This is a summary of a 420 page report on a sediment and soil loss study of five Illinois lakes and their watersheds conducted by the Illinois State Water Survey as project 20.085, sponsored by an agreement with the Illinois Institute for Environmental Quality and the Illinois Environmental Protection Agency. The work was done by John B. Stall and members of his staff beginning November, 1976, and completed December 31, 1977. The data was gathered to support the development of a state plan for abatement of agricultural non-point sources of pollution, under provisions of Section 208 of the Water Pollution Control Act Amendments of 1972 (P.L. 92-500).

The primary purpose of this study was to provide basic understanding of soil erosion losses, sediment deposition, and sediment delivery rates for typical Illinois lakes. The sediment delivery rate is the percent of the gross soil erosion from the watershed which is delivered to the lake. Knowledge of watershed soil losses, the amount of sediment deposited in the lake, and the trap efficiency of the lake are required to calculate this rate.

Soil losses were calculated for the watersheds of Lake Vermilion, Lake Taylorville, Lake Springfield, Lake Carlyle, and Lake Shelbyville by use of the Universal Soil Loss Equation. Sediment volumes were measured for Lakes Vermilion, Taylorville, and Springfield. The locations of these lakes are shown in Figure 1.

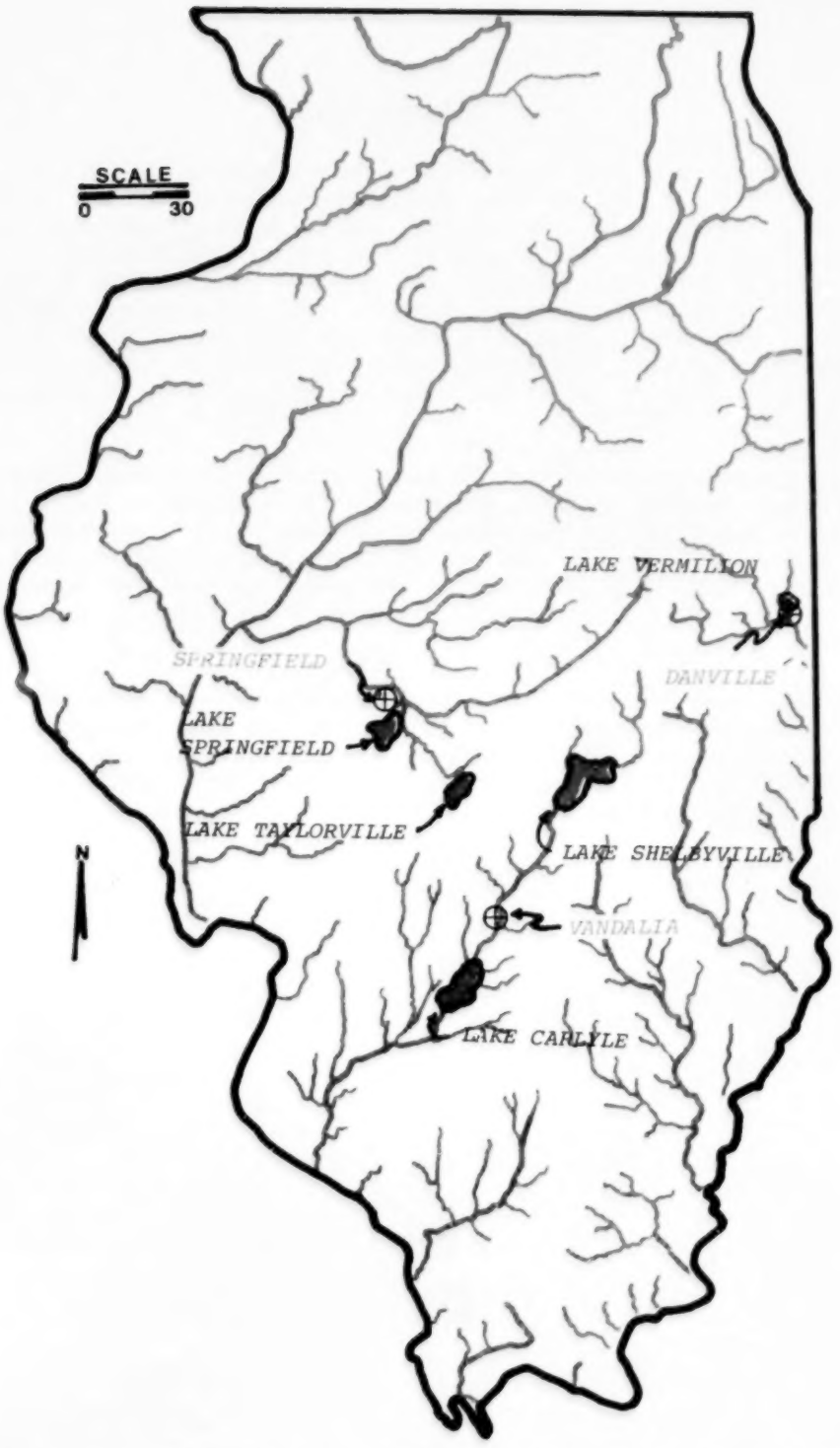

FIGURE 1: LOCATION OF THE FIVE LAKES INCLUDED IN THE STUDY OF SEDIMENT AND SOIL LOSS IN ILLINOIS.

CONCLUSIONS

1. The detailed calculations of soil loss for the watersheds of Lakes Vermilion, Taylorville, Springfield, Carlyle, and Shelbyville illustrated the value of the Universal Soil Loss Equation in quantifying potential sediment problems in any stream segment in Illinois.

2. Cropland was by far the major contributor of sediment in the watersheds studied.

3. Most of the erosion losses, 68%, came from land with less than 4% slope.

4. Soil loss rates per acre per year increased rapidly as slope increased up to about 7%, at which point rates tended to level off, probably because the steeper slopes were more often covered by hay, pasture, or forest.

5. A relatively small percent (18.4) of the land in the watersheds had average soil losses above 5 tons per acre per year.

6. Subwatersheds within the watersheds studied showed considerable variation in average soil loss rates. Values ranged from 2.4 to 7.2 tons per acre per year in the Lake Taylorville watershed, for example.

7. The results showed that the coarser soil particles were deposited in the streambeds while the finer silts and clays were deposited in the lakes.

8. The current yearly loss of the original lake storage capacity due to sediment was highest for Lake Taylorville with a 1.04% loss and lowest for Lake Springfield with a .29% loss. Lake Vermilion's yearly loss was .60%. When compared with loss rates for prior periods on Lakes Vermilion and Springfield, the trend was mixed with Lake Vermilion showing a slight decrease and Lake Springfield a slight increase.

9. Sediment delivery rates were 25% for Lake Vermilion, 34% for Lake Taylorville, and 24% for Lake Springfield. These rates were 10% to 16% higher than might have been estimated had standard sediment delivery curves been used.

RESULTS

Watershed Soil Losses

The basic tool used to estimate soil erosion was the Universal Soil Loss Equation, described as follows: $A=RK\underline{LS}CP$

where A is the computed soil loss per acre per year
R is the rainfall factor
K is the soil erodibility factor
$\underline{LS}$ is the slope and slope length factor
C is the cropping management factor
P is the erosion control practice factor

Two major data collection tasks were undertaken. The first was to measure the acreages of various soil types which occurred in the watershed. The base data showing acres of the various soil mapping units for Carlyle and Shelbyville was arrived at from the Conservation Needs Inventory (expanded 2% sample data). A procedure was set up to sample 160 acre plots to gather representative soil data for both the Vermilion and Taylorville watersheds. Approximately 40% of the Vermilion watershed, 50% of the Taylorville watershed, and nearly all of the Lake Springfield watershed had previously been soil mapped.

To speed up gathering soil map acreage data, a digitizer was used as a tool to produce a computer readable map. A package of computer programs was then used to obtain soil type data for any part or for the whole watershed.

The second data collection task was to assign factors for the USLE for all the soil types in the watershed.

The rainfall factor used varied from a low of 175 for Lake Vermilion watershed to a high of 200 for the Lake Carlyle watershed. The geographic locations as related to a iso-erodent map plotted by Wischmeier and Smith (1961) determined the rainfall factor used for each watershed.

Soil erodibility factors (K values) were selected for the major soil series in each watershed from a USDA Soil Conservation Service (1974) publication.

A combined slope and slope length factor (LS value) was used. The judgement of Soil Conservation field men was used to determine slope amounts and lengths for each major soil in each watershed.

The crop management factor (C value) was also arrived at by assistance of SCS field people. The method varied somewhat from watershed to watershed and in some cases field people from Extension Service and Agricultural Conservations Services participated. In each watershed the land use and proportion of land in various crops was determined for each soil mapping unit. Field observations were made to determine the land use and cropping pattern for the major soil mapping units in all watersheds except Carlyle and Shelbyville. In these two larger watersheds, several field people, representing all counties involved, met and pooled their knowledge to arrive at a consensus of the cropping pattern for each mapping unit.

A conservation practice factor of 0.8 was assigned to most sloping crop land. However, depressional or very flat land was assigned a "P" value of 1.0. It was assumed that nearly half of the sloping row crop land would be incidentally formed across the slope or on the contour. However, this was assumed not true on flatter land because here most farmers lay out fields with rows parallel to slope direction for better row drainage.

Annual erosion losses for the watersheds of the five Illinois lakes studied are presented in Table 1. Average erosion rates varied from a low of 3.26 tons/acre/year for the Lake Vermilion watershed to a high of 4.61 tons/acre/year for the Lake Carlyle watershed.

A detailed analysis of the soil losses was made for the watersheds of Lakes Vermilion, Taylorville, and Springfield. Erosion losses by land use categories are shown in Table 2. In these three watersheds, greater than 95% of the gross erosion losses were from cropland.

Soil losses are summarized by slope categories in Table 3. The highest percent soil loss came from the lowest slope category. Most (68%) of the soil losses came from land with less than 4% slope. Soil loss rates per acre per year increased rapidly as slope increased up to about 7%, at which point rates tended to level off, probably because the steeper slopes were more often covered by hay, pasture, or forest.

Table 4 summarizes the land in various erosion categories for the watersheds of Lakes Vermilion, Taylorville, and Springfield. Only 18.4% of the land in the three watersheds had erosion losses above 5 tons per acre per year.

Soil losses were calculated for 10 subwatersheds for each of the three lakes. The range of variation in soil loss rates between subwatersheds are given in Table 5. The widest range occurred in the Lake Taylorville watershed where the average soil losses for the lowest subwatershed was 2.45 tons per acre per year and the highest subwatershed was 7.18.

Table 1. Annual erosion losses for the watersheds of five Illinois lakes, 1977.

Lake Name	Watershed Size* (acres)	Gross Erosion (tons/yr.)	Average Erosion Rate (tons/acre/yr.)
Vermilion	199,400	653,000	3.26
Taylorville	83,506	299,900	3.60
Springfield	165,366	655,398	3.96
Shelbyville	662,400	2,500,000	3.72
Carlyle	961,920	4,400,000	4.61

*excluding area of lake

Table 2. Erosion losses by land use categories for the watersheds of three Illinois lakes, 1977.

Lake Name	Watershed Land Use Category			
	Crop Land	Pasture Land	Wood Land	Other Land
Vermilion				
Land Use (%)	91.5	2.9	3.4	2.2
Gross Erosion (%)	96.2	.1	1.8	1.9
Soil Loss (tons/ac/yr)	3.08	.96	1.50	2.60
Taylorville				
Land Use (%)	82.9	8.4	6.3	2.3
Gross Erosion (%)	95.1	.4	2.0	2.5
Soil Loss (tons/ac/yr)	4.13	.18	1.16	3.8
Springfield				
Land Use (%)	88.2	8.2	1.3	2.3
Gross Erosion (%)	95.4	.6	1.4	2.7
Soil Loss (tons/ac/yr)	4.28	.27	4.23	4.60

Table 3. Soil losses by slope categories, average for the watersheds of Lakes Vermilion, Taylorville, and Springfield, Illinois, 1977.

Slope (%)	Soil Loss (tons/ac./yr.)	% of Watershed (average)	% of Soil Loss (average)
0-2	2.1	72	42
2-4	5.3	17	26
4-7	12.8	7	24
Greater than 7	9.0	4	8

Table 4. Percent of land in various erosion categories for the watersheds of three Illinois lakes, 1977.

	Erosion Categories (tons/acre/year)			
Lake Name	0-2	2-5	5-10	10+
Vermilion	46.5	31.0	20.7	1.9
Taylorville	44.9	44.2	4.1	6.8
Springfield	29.4	48.8	15.4	6.4
Average	40.3	41.3	13.4	5.0

Table 5. Range of variation in soil loss rates between subwatersheds of three Illinois lakes, 1977.

Lake Name	Average Soil Loss (tons/ac./yr.)	
	Low Subwatershed	High Subwatershed
Vermilion	2.67	4.90
Taylorville	2.43	7.18
Springfield	3.05	5.25

Since nearly all of the Lake Springfield watershed had previously been soil mapped, the decision was made to study the reliability or accuracy of using various soil map sampling rates. The percents sampled were 2, 5, 10, 30, 50, and 100. The samples used were randomly selected from the entire watershed.

The results (Table 6) show that the error in calculated soil loss increases as the sample size decreases. A 2% sample of watershed soils introduces only an error of plus or minus about 12% in the calculated annual soil loss.

Table 6. Error in calculated soil loss from the watershed of Lake Springfield, Illinois, using various sized soil mapping samples.

% of Maps Used	USLE Predicted Soil Loss Using 100% Sample (Average tons/ac./yr.)	Average % Error	Range (tons/ac./yr.)
100	3.96	0	3.96
50	3.96	1.5	3.90 to 4.02
30	3.96	3.2	3.83 to 4.09
10	3.96	11.2	3.51 to 4.41
5	3.96	9.1	3.60 to 4.32
2	3.96	12.1	3.48 to 4.44

Sediment Surveys

Depths of sediment in Lakes Vermilion, Taylorville, and Springfield were measured along cross-section lines monumented for future reference. Sediment measurements were made at 50 or 100 feet intervals along these lines. Most measurements were made using a 2-inch diameter aluminum sounding pole. The pole was first lowered to the present lake bottom, then pushed through the accumulated sediment until the original bottom was encountered. Other depth measurements were made using conventional leveling techniques.

Sediment survey results are presented in Table 7. Lake Vermilion has lost a total of 45.5% of its original storage capacity due to sediment since its creation in 1925. Lake Taylorville has lost 15.9% of its storage since 1962 and Lake Springfield has lost 12.4% since 1934 from sediment deposition. The percent of the original storage capacity lost per year was also calculated. The current yearly loss of the original lake storage capacity due to sediment was highest for Lake Taylorville with a 1.04% loss and lowest for Lake Springfield with a .29% loss. Lake Vermilion's yearly loss was .60%. When compared with loss rates for prior periods on Lakes Vermilion and Springfield, the trend was mixed, with Lake Vermilion showing a slight decrease and Lake Springfield a slight increase.

Sediment Analysis

As a part of this project, sediment samples were taken from Lakes Carlyle, Shelbyville, Vermilion, Taylorville and Springfield and their watersheds. Streambed samples were taken at 50 locations and lake sediment samples were taken at 81 locations. A mechanical analysis was made of 94 samples giving soil particle size distribution. The average size distribution of sediment for both streambed and lakebed samples is presented in Table 8.

The analysis shows that the larger soil particles were deposited primarily in the streambeds while the finer clay material were deposited in the lake. On an average, the lake sediment was a little over 3 times higher in clay content than the streambed sediment. In Lake Carlyle the lake sediment was over 5 times higher in clay than the stream sediment.

The sediment samples collected were also analyzed for pesticides and other chemicals by the Illinois Environmental Protection Agency. Results are summarized in Appendix A.

Table 7. Sediment survey results for three Illinois lakes.

Lake Name/ Year Surveyed	Yrs. Between Surveys	Size (Acres)	Capacity			Sediment		
			ac.-ft.	Total % Loss	Annual % Loss Btwn Surveys	Total Accumulated (ac.-ft.)	Ave. Annual Accumulation from Wtrsd btwn Surveys	
							ac.-ft.	tons/ac.
Vermilion								
1925	0	775	8,514	-	-	-	-	-
1963	38.3	696	5,318	37.5	.98	3,196	83.4	.495
1976	13.3	608	4,641	45.5	.60	3,873	50.9	.468
Taylorville								
1962	0	1,148	9,406	-	-	-	-	-
1977	15.3		7,914	15.9	1.04	1,492	97.6	1.0
Springfield								
1934	0	4,177	61,039	-	-	-	-	-
1948	14.6		58,380	4.36	.30	2,659	182	1.03
1965	17.0		55,632	8.86	.26	5,407	162	.83
1977	12.0	4,025	53,478	12.4	.29	7,561	180	.81

Table 8. Average size distribution of sediment from five Illinois lakes and their watersheds, 1977.

Lake Name	% Clay ($< 2\mu$)	% Silt (2-50μ)	% Sand ($>50\mu$)
Carlyle			
Stream	7.3	17.1	75.6
Lake	37.5	49.4	13.1
Shelbyville			
Stream	12.8	26.0	61.2
Lake	34.4	47.7	17.9
Vermilion			
Stream	10.1	24.4	65.6
Lake	33.8	44.5	21.7
Taylorville			
Stream	16.6	48.5	34.9
Lake	52.0	45.2	2.8
Springfield			
Stream	16.5	55.1	10.5
Lake	42.8	46.7	54.9
Ave. of all lakes			
Stream	12.3	32.8	54.9
Lake	39.3	47.5	13.2

Trap Efficiency of Lakes

The trap efficiency of a lake or reservoir, based on the capacity-inflow ratio, is the percent of the sediment entering the lake which is deposited in the lake. The remaining portion of all the sediment passes through the lake, over the spillway, and on downstream.

The trap efficiency curve developed by Brune (1953) for fine sediment was used to calculate the trap efficiencies of Lakes Vermilion, Taylorville, and Springfield. This widely accepted and used curve was based on observations of 44 lakes in the U.S.

The trap efficiency of the three lakes was calculated to be 92% for Lake Springfield, 82% for Lake Taylorville, and 59% for Lake Vermilion.

Sediment Delivery to Lakes

The amount of sediment delivered to a lake, expressed as a percent of the gross erosion losses for the watershed, is termed the sediment delivery rate. For Lakes Vermilion, Taylorville, and Springfield, the amount of sediment delivered to the lake was calculated by adjusting the measured average amount of sediment deposited yearly for trap efficiency. The amount of sediment delivered to each lake was then divided by the average annual soil loss for the watershed to give delivery rates of 25% for Lake Vermilion, 34% for Lake Taylorville, and 24% for Lake Springfield (Table 9).

The sediment delivery rates for the three lakes studied are 10% to 16% higher than would have been estimated had the widely accepted Roehl curve been used. The three Illinois lakes may have higher delivery rates because their sediments are higher in clay than were the sediments of the lakes used as a basis for the Roehl curves.

Table 9. Sediment Delivery to three Illinois lakes, 1977.

Lake Name (Watershed Area*)	Sediment Deposited (tons/ac/yr)	Trap Efficiency (%)	Sediment Delivered (tons/ac/yr)	Watershed Soil Loss (tons/ac/yr)	Sediment Delivery (%)
Vermilion (312 sq. mi.)	.49	59	.83	3.26	25
Taylorville (130 sq. mi.)	1.0	82	1.22	3.60	34
Springfield (258 sq. mi.)	.89	92	.97	3.96	24

*excluding area of lake

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APPENDIX A

ANALYSES OF SEDIMENT SAMPLES FROM FIVE ILLINOIS LAKES AND THEIR WATERSHEDS FOR PESTICIDES AND OTHER CHEMICALS

Pesticide Analyses of Sediment Samples

Sediment samples collected from Lakes Vermilion, Taylorville, Springfield, Carlyle, Shelbyville and their watersheds were analyzed for dieldrin, heptachlor epoxide, atrazine, trifluralin, phorate, counter, chlordane, and PCB concentrations. Average levels of dieldrin, heptachlor epoxide, and chlordane for samples with concentrations of these pesticides above detection limits are given in Table 10.

Sediment from Lake Springfield was relatively high in dieldrin while that from Lake Vermilion was comparatively high in heptachlor epoxide. Sediment from Lake Carlyle was lowest in both pesticides. The range from highest to lowest value for these two pesticides was wide in all lakes, with the greatest range (116.0 to 1.1) for dieldrin appearing in Lake Shelbyville and the greatest (16.0 to <1.0) for heptachlor epoxide in Lake Vermilion (Table 10).

Chlordane was found to be above the detection limit of 10 ppb in six Lake Springfield samples, five Lake Carlyle samples, five Lake Shelbyville samples, and 16 out of the 23 samples for Lake Taylorville. The 16 Lake Taylorville samples averaged 32.2 ppb chlordane, a higher concentration than the other watersheds (Table 10).

Table 11 shows the levels of dieldrin, heptachlor epoxide, and chlordane in streambed sediment as compared to lakebed sediment. The data show that dieldrin is substantially higher, and heptachlor epoxide and chlordane are slightly higher, on the average in lakebed sediments.

The herbicide atrazine did not exceed 500 ppb, the minimum detection limit, in any sample in any watershed. Another herbicide, trifluralin, did not exceed 5 ppb in Lakes Vermilion and Carlyle, but did exceed this level in one sample from Lake Shelbyville (18 ppb), four samples from Lake Taylorville (average 13.2 ppb), and 11 samples from Lake Springfield. The 11 samples from Lake Springfield averaged 11.9 ppb.

Analysis for both phorate and counter showed all samples in all watersheds to be below the detection limit of 30 ppb.

PCB concentrations of 58 and 120 ppb were found in two samples from Lake Shelbyville. Both samples were from streambeds above the lake.

Table 10. Dieldrin, heptachlor epoxide, and chlordane concentrations (micrograms per kilogram = ppb) in sediment samples from five Illinois lakes and their watersheds, 1977.

Lake Name	Dieldrin				Heptachlor Epoxide				Chlordane			
	No. of Samples Detectable/ Total	Mean*	Max.	Min.	No. of Samples Detectable/ Total	Mean*	Max.	Min.	No. of Samples Detectable/ Total	Mean*	Max.	Min.
Vermilion	19/ 21	15.1	83.5	<1.0	19/ 21	8.1	16.0	<1.0	0/ 0			
Taylorville	23/ 23	12.1	54.0	1.7	20/ 23	5.9	14.0	<1.0	16/ 23	32.2	79.0	<10.0
Springfield	32/ 33	23.9	48.0	<1.0	28/ 33	5.3	13.0	<1.0	6/ 33	24.1	32.0	<10.0
Shelbyville	22/ 22	15.4	116.0	1.1	11/ 22	1.8	8.0	<1.0	5/ 22	13.4	19.0	<10.0
Carlyle	28/ 31	3.4	13.0	<1.0	9/ 31	1.2	2.5	<1.0	5/ 31	17.0	25.0	<10.0
Mean - all lakes		14.1				4.5				21.7		

*Means only include values for samples with concentrations of the pesticides above detection limits.

Table 11. Comparison of average dieldrin, heptachlor epoxide, and dieldrin concentrations (micrograms per kilogram = ppb) in streambed and lakebed sediments, Illinois, 1977.

Sample Type	Dieldrin		Heptachlor Epoxide		Chlordane	
	No. of Samples Detectable/total	Mean* ppb	No. of Samples detectable/total	Mean* ppb	No. of Samples detectable/total	Mean* ppb
Streambeds	46/50	9.5	34/50	4.1	14/42	19.5
Lakebeds	78/80	17.0	53/80	4.2	22/68	21.5

*Means only include values for samples with concentrations of the pesticides above detection limits.

Chemical Analyses Of Sediment Samples

Eleven chemical elements were analyzed in sediment samples taken from Lakes Vermilion, Taylorville, Springfield, Carlyle, and Shelbyville and their watersheds. Those results have been tabulated in Table 12.

Some general conclusions are as follows:

1. Elements such as iron, manganese, and phosphorous found in high concentrations in sediment are also found abundantly in Illinois soils.

2. Most lakebed samples showed higher in the elements analyzed than did the watershed streambed samples. This is probably because the lakebed samples are also higher in the finer clay fractions which have a much higher capacity to hold elements than do coarser sands and silts.

3. In general, Lake Carlyle samples were lower in the minerals tested than were samples from the other lakes. One noteable exception was manganese. This relationship may be attributable to a marked difference in soils in the watershed above Lake Carlyle as compared to the other watersheds. The soils of the Carlyle watershed are much older geologically and more weathered. They are characteristically lower in the more soluble elements and have a lower pH. Acid soils having a low pH value tend to have higher amounts of soluble iron and manganese. This may account for the higher manganese in the sediment from Lake Carlyle.

Table 12. Summary of chemical analyses of sediment samples for five Illinois lakes and their watersheds 1977.

SAMPLE SOURCE	NUMBER OF SAMPLES	DATE COLLECTED	PARAMETER (micrograms per gram = ppm; air dried weight, 40°C, 7 days) TOTAL CADMIUM	TOTAL COPPER	TOTAL CHROMIUM	TOTAL IRON	TOTAL LEAD	TOTAL MERCURY	TOTAL ZINC	TOTAL ARSENIC	TOTAL MANG-ANESE	TOTAL NICKEL	TOTAL PHOS-PHORUS
Lake Vermilion													
Mean	21	1-77											
Maximum			.4	26.1	13.3	17,414	21.9	.039	85.6	5.6	835	23.5	292
Minimum			.6	40	24	28,000	36	.058	170	10	2,700	36	460
Watershed streambed	8		.1	8	5	7,900	8.7	.018	43	2.6	450	12	150
Lakebed	13		.4	29.8	7.3	11,088	17	.034	57.6	5	875	17.3	260
			.35	23.8	17.1	21,307	24.9	.043	102.8	6	811	27.5	312
Lake Taylorville													
Mean	23												
Maximum			.4	19.2	27.6	18,348	21.7	.12	72.6	6.5	729		599
Minimum			.5	25	96	25,000	56	.19	99	14	1,600		914
Watershed streamed	8	6-77	.0	5	6	9,000	11	.06	32	3.2	320		179
Lakebed	15	5-77	.2	10.7	9.1	12,500	17.3	.07	45.9	4.9	562		327
			.5	23.8	37	21,467	24.1	.14	86.8	7.3	818		744
Lake Springfield													
Mean	33												
Maximum			.5	27.6	28.3	18,267	23.9	.12	84.1	6.6	798		589
Minimum			1.0	85	200	33,000	40	.23	36	10	2,200		864
Watershed streambed	10	6-77	.0	8	7	9,800	10	.05	200	3.4	620		353
Lakebed	23	5-77	.5	12.5	9.2	13,280	16.9	.07	51	5.9	743		450
			.5	34.1	36.7	20,435	26.9	.13	98.5	6.9	822		650
Lake Carlyle													
Mean	31	6-77	0.3	14.3	10.7	14,861	14.5	.09	55.6	4.7	881		433
Maximum	-		0.5	26	20	51,000	46	.15	90	16	2,300		905
Minimum	-		0.0	5	3	3,500	1	.05	15	1.9	200		106
Watershed streambed	13		0.04	7.1	5.3	7,515	5.3	.07	26.1	3.4	545		231
Lakebed	18		0.5	19.4	14.6	20,167	21.0	.11	77	5.6	1,124		579
Lake Shelbyville													
Mean	23	6-77	0.45	14.5	13.7	12,783	18.7	.09	59.4	4.0	540		416
Maximum			0.5	33	49	21,000	33	.20	100	6.5	1,600		866
Minimum			0	5	5	6,000	5	.04	25	1.8	160		174
Watershed streambed	11		0.4	10.8	12.5	8,427	12.3	.07	43.8	2.8	245		309
Lakebed	12		0.5	17.8	14.9	16,775	24.7	.11	73.7	5.1	810		515

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